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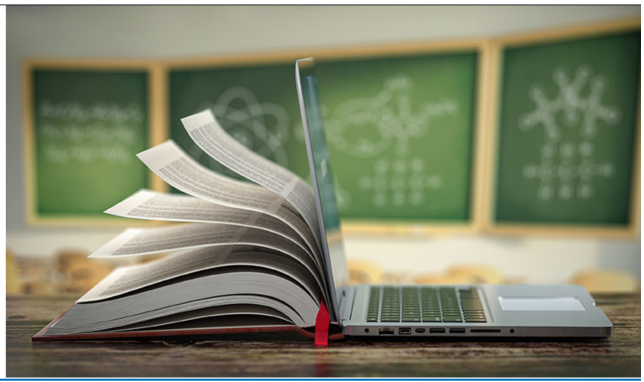
To cite this article: Y A Ivanov *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **972** 012027



Energy Efficiency Increasing of Premises through Type of Illuminating Lamps

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Abstract. The study is considered issues of energy efficiency improving of exhibit and other halls with a large number of people. In such cases maintenance of required parameters of intensity of illumination is accompanied by heat emissions from the lighting, constituting significant part of the total heat gain in the room that increases load on the system of microclimate maintenance. By the example of an exhibit hall in a multifunctional complex it is shown that replacement of incandescent lamps for energy-saving lamps allows to reduce energy consumptions for lighting and also capital and operating expenses on the microclimate control systems. At the same time, temperature and humidity conditions and air velocity are supported, optimal conditions for staff, equipment and machinery are created.

Key words: Energy efficiency of premises; lighting; microclimate; air changes; economic comparison; energy-saving.

1. Introduction

The premises of the exhibition, concert and conference halls are connected with the staying of a large number of people. Therefore, it needs to maintain certain level of lighting and microclimate parameters (temperature and humidity conditions and air velocity).

For such premises, heat emissions from the lighting constitute significant part of the total heat gain and negatively affect the indoor microclimate state.

In such cases, the replacement of incandescent lamps to energy-saving is one of the measures aimed to the room energy efficiency improving, maintenance of comfortable microclimate parameters and creating of optimal conditions for the staff, equipment and machinery [1]. At the same time heat emissions into the room are reduced, that allows to decrease energy consumptions as for lighting as for preparing and distributing of supply air.

2. Object of research

An exhibit hall in the multifunctional complex with the total area is 1675 m2 (with administrative premises) with 168 people staying. It was chosen as the research object. Indoor air temperature for cold period of year (CP), transient conditions (TC) and warm period (WP) equals twz=+20°C.

This article is considered two options of hall lighting: the first is energy-saving lamps, the second is incandescent lamps. And air changes for these options are compared.

Option 1: Energy-saving lamps (EL).

1. Heat gain from artificial lighting is defined as:

$$Q_l = E \cdot F_r \cdot q_l \cdot \eta_l \quad (1)$$

where E - normalized intensity of lighting, accepted according [2]; for exhibit halls $E = 300\ lx$;
F_r- room square, m^2, $F_r = 1675\ m^2$;
q_l- specific heat emission per 1 Lux, $W/(lx \cdot m^2)$, accepted $q_l = 0.038\ W/(lx \cdot m^2)$, according [2];
η_l- part of heat entering to the room, accepted $\eta_l = 1$ as heat source is indoors, [2].

$$Q_l = 300 \cdot 1675 \cdot 0.038 = 19100\ W$$

2. Heat gains from people, W:

Sensible heat emission:

$$Q_s = q_s \cdot n \cdot k \quad (2)$$

where q_s – sensible heat emission from one person, W, accepted according [3].
n – number of people in the room;
k – corrective factor k =1, the calculation is carried out at maximum heat emission.

$$Q_s = 105 \cdot 168 \cdot 1 = 17640\ W$$

Total heat emission is determined by analogy: Q_t=34440 W
Moisture emission: W = 23520 g/h
Carbon dioxide emissions: G = 12600 g/h
3. Heat gains from solar radiation are calculated according [3] and equal $Q_{s.r.}$=16230 W
Received heat gains are shown in the table 1.1.

Table 1.1. Calculation of heat emissions using energy-saving lamps

Period of the year	Heat emissions, W						Pollution emissions, g/h	
	$Q_{s.r.}$	Q_l	From people		Calculated		W	CO_2
			Q_s	Q_t	Q_s	Q_t		
1	2	3	4	5	6	7	8	9
CP	-	19100	17640	34440	36740	53540	23520	12600
TC	-	19100	17640	34440	36740	53540	23520	12600
WP	16230	19100	17640	34440	52970	69770	23520	12600

Option 2: Incandescent lamps (IL).

1. In such case $q_l = 0.067\ W/(lx \cdot m^2)$ and value of heat emission from incandescent lamps is:

$$Q_l = 300 \cdot 1675 \cdot 0.067 = 33670\ W$$

The values of other heat gains and pollution emissions will remain unchanged. The calculation results are shown in the table 1.2.

Table 1.2. Calculation of heat emissions using incandescent lamps

Period of the year	Heat emissions, W						Pollution emissions, g/h	
	$Q_{s.r}$	Q_l	From people		Calculated		W	CO_2
			Q_s	Q_t	Q_s	Q_t		
1	2	3	4	5	6	7	8	9
CP	-	33670	17640	34440	51310	68110	23520	12600
TC	-	33670	17640	34440	51310	68110	23520	12600
WP	16230	33670	17640	34440	67540	84340	23520	12600

In this way incandescent lamps replacing on energy-saving lamps decreases heat emission from lighting for 14.5 kW.

Air change calculation for considered variants of lighting

Option 1: Energy-saving lamps (EL)

1. Air change rate for assimilation of sensible heat excess, L_h m^3/h, is determined as:

$$L_h = \frac{3.6 \cdot Q_h}{1.2 \cdot (t_l - t_{in})} \tag{3}$$

where Q_h – excess of sensible heat emission, W;
t_l, t_{in}– temperatures of supply and exhaust air, °C.
CP:

$$L_h = \frac{3.6 \cdot 36740}{1.2 \cdot (23 - 18)} = 22040\ m^3/h$$

TC: $L_h^{TC} = 13780$ m^3/h
WP: $L_h^{WP} = 31780$ m^3/h

2. Air change rate for assimilation of total heat excess, L_{hf} м^3/ч is determined as:

$$L_h = \frac{3.6 \cdot Q_{hf}}{1.2 \cdot (I_l - I_{in})} \tag{4}$$

where Q_{hf} – excess of total heat emission,W;
I_{in}, I_l - enthalpy of supplied and exhaust air, J/kg.

Cold period
t_{ext}=-32°C
I_{ext}=-31.6 kJ/kg
$I_{вв}$=t+(1.96t+2500t)d
$-31.6 = -32 + (1.96 \cdot 32 + 2500) \cdot d_{ext}$
$d_{ext} = 1.64 \cdot 10^{-4} kg/kg = 0.17 g/kg$
t_{in}=18°C
t_l=23°C
$Q_{hf} = 53540\ \text{Вт} = 53{,}54\ kW$
$W = 23520\ g/h = 23{,}52\ g/s$

Determination of heat and humidity ratio:

$$E = \frac{Q_{hf} \cdot 3600}{W} \tag{5}$$

$$E = \frac{53.54 \cdot 3600}{23.52} = 7648\ kJ/kg$$

Determination of the point characterizing the supply air parameters:
d_{in}=0.17 g/kg
I_{in}=19 kJ/kg

Determination of the point characterizing the exhaust air parameters:
d_l=1.2 g/kg
I_l=26 kJ/kg

$$L_{hf} = \frac{3.6 \cdot 53540}{1.2 \cdot (26 - 19)} = 22910\ m^3/h \tag{6}$$

The process of air parameters change in CP is shown on figure 1.

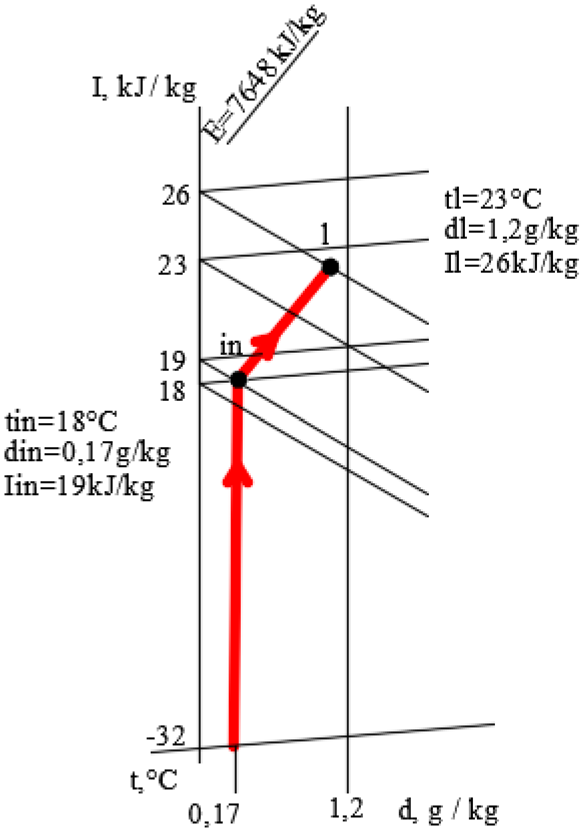

Figure 1. The process of air parameters change in CP.

Air changes rate for TC and WP are determined by analogy.
TC: $L_{hf}^{TC} = 12360$ m^3/h
WP: $L_{hf}^{WP} = 36590$ m^3/h

3. Air change rate for assimilation of moisture excesses, L_w m^3/h, is determined as:

$$L_w = \frac{W}{1.2 \cdot (d_l - d_{in})} \tag{7}$$

where W – moisture excesses, g/h;
d_{in}, d_l – moisture content of supply and exhaust air, g/kg. Values of air moisture content d_{in}, d_l are determined with I-d- diagram of humid air.

$$L_w = \frac{23520}{1.2 \cdot (1.2 - 0.17)} = 19030\ m^3/h$$

TC: $L_w^{TC} = 11530$ m^3/h
WP: $L_w^{WP} = 19600$ m^3/h

4. Air change rate for assimilation of pollutions, L_G m^3/h, is determined according [4]:

$$L_G = \frac{m_{po}}{q_l - q_{in}} \tag{8}$$

where m_{po} – mass of harmful substances entering the room air, g/h;

$q_l = 2g/m^3$ – concentration of harmful substances in exhaust air (for institutions);
$q_{in} = 0.8g/m^3$ – concentration of harmful substances in supply air (concentration of harmful substances is accepted for large cities).

CP, TC and WP:

$$L_G = \frac{12600}{2 - 0.8} = 10500m^3/h$$

The results of air changes rates calculation using energy-saving lamps are shown in table 1.3.

Table 1.3. The results of air changes rate calculation using energy-saving lamps

Period of the year	Air supply volume, m^3/h			
	on excess of sensible heat emission L_h	on excess of total heat emission L_{hf}	on moisture excesses L_w	on the mass of pollutions L_{CO2}
CP	22040	22910	19030	10500
TC	13780	12360	11530	10500
WP	31780	29900	19600	10500

Option 2: Incandescent lamps (IL).

Air change calculation for this option is performed similarly to option 1. The results of air changes calculations using incandescent lamps are shown in table 1.4.

Table 1.4. The results air changes rate calculation using incandescent lamps

Period of the year	Air supply volume, m^3/h			
	on excess of sensible heat emission L_h	on excess of total heat emission L_{hf}	on moisture excesses L_w	on the mass of pollutions L_{CO2}
CP	30790	29190	19600	10500
TC	19240	18580	11530	10500
WP	40520	35720	19600	10500

The maximum value is accepted as calculating.

Option 1: 31780 m^3/h.

Option 2: 40520 m^3/h.

In this way replacing of incandescent lamps to energy-saving decreases air supply rate for 8740 m^3/h. Consequently, it needs smaller air handling unit, also capital and operating expenses are reduced.

3. The research results

Performing economic comparison of variants is based on recommendations [5]. As initial information it is accepted:

- time of electricity consumption per year is τ =2920 hours;
- the number of lighting lamps in the exhibition hall: N=300 pieces;
- incandescent lamp capacity: P_{IL}=60 W;
- energy-saving lamp capacity: P_{EL}=11 W;

- electricity tariff in Yekaterinburg: T_e=3.96 rub/kW·h;
- cost of energy-saving lamp: 95 rubles

Electricity consumption per year is determines as:

$$W = \tau \cdot P \cdot N \tag{9}$$

$$W_{IL} = 2920 \cdot 60 \cdot 300 = 52560\ kW \cdot h$$

$$W_{EL} = 2920 \cdot 11 \cdot 300 = 9636\ kW \cdot h$$

Energy costs per year:

$$Z = W \cdot T_e \tag{10}$$

$$Z_{IL} = 52560 \cdot 3.96 = 208140\ rub/year$$

$$Z_{EL} = 9636 \cdot 3.96 = 38160\ rub/year$$

Saving electricity in natural terms:

$$\Delta W = W_{IL} - W_{EL} \tag{11}$$

$$\Delta W = 52560 - 9636 = 42924\ kW \cdot h$$

Energy cost savings:

$$\Delta Z = Z_{IL} - Z_{EL} \tag{12}$$

$$\Delta Z = 280140 - 38160 = 241980\ rub./year$$

Cost of energy-saving lamps:

$$EL = N \cdot 95 \tag{13}$$

$$EL = 300 \cdot 95 = 28500\ rubles$$

The payback period with energy-saving lamps is:

$$\tau_p = \frac{EL}{\Delta Z} \tag{14}$$

$$\tau_p = \frac{28500}{241980} = 0.112\ years = 43\ days$$

4. Conclusion

In this way replacement of incandescent lamps to energy-saving lamps in an exhibit hall leads to energy cost savings and pays for itself in 43 days. Herewith heat emissions from lighting are reduced for 14,5 kW, that allows air change rate to decrease for 8740 m3/h. Consequently, power of microclimate control system, capital and operating expenses are reduced.

This variant was considered by customer and accepted for implementation on the facility.

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